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TECHNICAL REPORT R10-TP-23
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METHYLCYCLOHEXENONE (MCH) TO
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IN SOUTH-CENTRAL ALASKA

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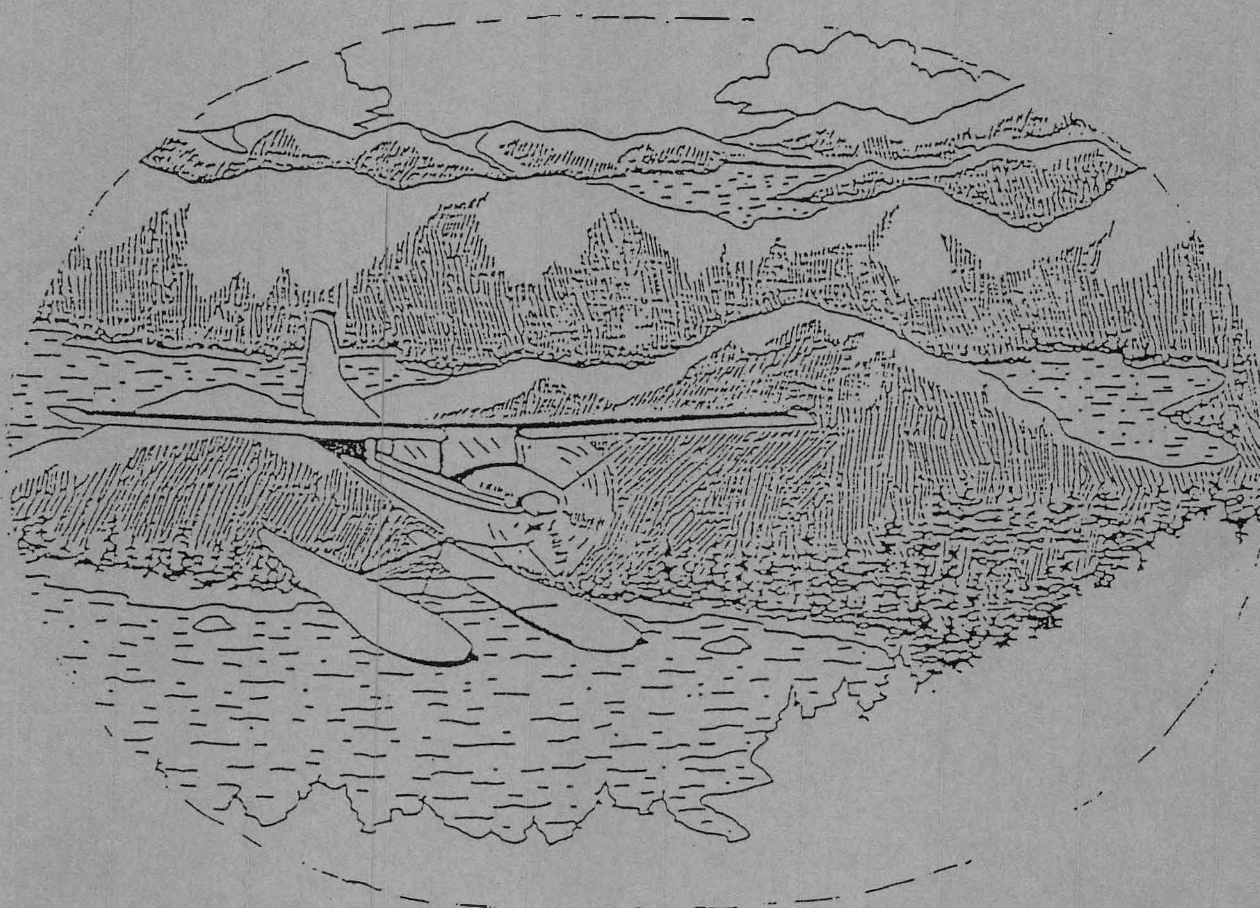

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ABSTRACT

The anti-aggregation pheromone (MCH) was tested for the prevention of spruce beetle buildup in spruce right-of-way debris near Tyonek, Alaska. A granular controlled release formulation was tested with an aerial and ground application at two dosage rates each: 4.6 and 9.2 kg/ha; 9.2 and 13.6 kg/ha, respectively. There were no significant differences in numbers of spruce beetle attacks and progeny produced between treatments and untreated control plots. The lack of significance was, in part, due to the low endemic spruce beetle population along the right-of-way resulting in low attack levels on the untreated check material. Thus, there was not significant beetle pressure to test the effectiveness of MCH treatments.

INTRODUCTION

The spruce beetle, *Dendroctonus rufipennis*, is a major killer of spruce across Canada and from the southern Rocky Mountains to Alaska (Safranyik 1985, Schmid and Frye 1977, Werner et al. 1977, Holsten et al. 1991). During the last 15 years, millions of acres of spruce in Alaska have been infested (Holsten 1990, USDA For. Ser. 1989). Much of the loss has occurred in areas with high-value trees such as campgrounds, recreational areas, hiking trail systems, and small communities. The death of individual trees and entire stands represents large annual losses in forest productivity and wildlife habitat. Beetle-killed timber increases fuel loads within stands which increases the risk of catastrophic wildfires. Beetle populations have expanded throughout south-central Alaska from 1974 on the Kenai Peninsula including the Chugach National Forest and Kenai National Wildlife Refuge and the west side of Cook Inlet in the Beluga-Tyonek area north to Judd Lake (Holsten 1990).

Past Alaska outbreaks have been associated with warm, dry summers and an accumulation of spruce debris from windthrown and felled trees which are highly productive breeding sites for spruce beetles. When beetle populations increase and a sufficient supply of breeding material is no longer available for colonization, beetles can infest nearby living trees, particularly in mature stands (Werner et al. 1977). Many factors contribute to increased spruce beetle activity and potential outbreaks but the most important is the continued stressed conditions under which a tree is growing. Such stressed conditions are caused by lack of silvicultural management which contributes to over-stocked stands that are composed of slow-growing, mature spruce trees.

Endemic levels of spruce beetles can be found in almost any spruce stand in Alaska (Werner and Holsten 1983). The general progession for development of an outbreak starts with the attack of a few "focus" trees in response first to primary host attractants such as monoterpenes or sesquiterpenes and secondly to

beetle-produced pheromones. The primary host attractants are usually more concentrated in stressed, slow growing trees (Birch et al. 1980, Hodges et al. 1979, Paine and Stephen 1987, Vite and Pitman 1969, Werner 1972a, 1972b, 1972c, Wood 1972). These trees then act as sites for population increases which are necessary for the beetles to reach epidemic levels. A new brood of adult beetles emerge from the focus trees and attack adjacent slower growing, less vigorous trees.

Presently, the strategies developed to mitigate the effects of spruce beetles on spruce stands in Alaska involve some form of stand manipulation or the use of chemical insecticides (Werner et al. 1977, Werner 1978). Among the recommended techniques for treatment of logging slash, felled, or windthrown green trees is the immediate salvage of the trees; or disposal by burning, chipping, or burying; or treating with EPA approved insecticides (Werner et al. 1983, 1984, 1986). These techniques are adequate where potential problem areas are accessible.

Recently the use of semiochemicals to manipulate bark beetle populations has gained interest. Semiochemicals are compounds that transmit messages between organisms and include attractants, aggregation and antiaggregation pheromones, inhibitors, and repellents. The objective of semiochemical deployment is to prevent attack or reduce the attack density of bark beetles to a level below the threshold density required for the development of brood trees. This type of strategy has several advantages. First, ready access to problem areas is not necessary since aerial application of semiochemicals is possible. Secondly, beetle resistance to treatment, with time, would be negligible since successful brood development would be prevented. Lastly, there would be little direct mortality to parasites and predators as occurs with some traditional insecticide treatments.

Spruce Beetle Chemical Communication

In 1977, Kinzer et al. (1971) identified methylcyclohexenol (seudenol) as one of the principal aggregation pheromones of the female Douglas-fir beetle, *D. pseudotsugae*. Vite and Pitman (1972) isolated seudenol in emergent unmated female Douglas-fir beetles which had fed in the phloem of Douglas-fir trees. The female beetle releases this pheromone soon after entering a suitable host to which it has been guided by volatile host chemicals (Rudinsky 1966). This pheromone attracts male beetles to the gallery constructed by the female. After the female mates with only one male, she releases MCH, the primary antiaggregation pheromone, which masks the pheromone seudenol and prevents other males from entering the gallery (Rudinsky 1969).

Seudenol (one of two beetle produced aggregating attractants, the other being frontalin) has also been identified in spruce beetle females (Rudinsky 1973) and could account for the cross attraction between the Douglas-fir beetle and spruce beetle as described by Chapman and Dyer (1969). Dyer and Taylor (1968) found that one or more female spruce beetles boring in white spruce logs, in the absence of males, create an attraction to both sexes. Even one unmated female in a log attracted more beetles than logs without beetles or with pairs of male and female beetles. The attraction produced by unmated females lasted for three weeks. Dyer and Chapman (1971) concluded that frontalin triggers the process of aggregation of spruce beetles to white spruce. Spruce beetle attacks were induced on live spruce trees baited with 1 ml of frontalin and on adjacent spruce trees (Dyer 1973).

MCH has been shown to reduce the response of Douglas-fir beetles to an attractive source composed of frontalin, alpha pinene, and host resin (Rudinsky et al. 1972). Research by Furniss et al. (1974) confirmed the density regulation function of MCH. Controlled-release granular formulations containing 2% MCH were developed that eluted MCH in the laboratory at 0.5 ug/h for 60 days (Furniss et al. 1977). An aerial application

of a slow-release granular formulation reduced attacks by the Douglas-fir beetle by 92-97% and reduced brood by 93-99% in felled Douglas-fir logs (Furniss et al. 1981). A granular controlled-release formulation of MCH reduced spruce beetle infestations in Engelmann spruce by 55% (McGregor et al. 1984).

MCH was identified in 1974 as a major component of the spruce beetle pheromone complex. A granular formulation of MCH (3.6% at 10X dosage) reduced spruce beetle attacks on Sitka spruce by 93% for five weeks (Rudinsky et al. 1974). Attacks by male and female spruce beetles were reduced by 93% when Engelmann spruce were baited with MCH in Idaho (Kline et al. 1974). The addition of MCH (300 mg) to sticky traps baited with the nautral attractant (female infested bolts) as well as synthetic pheromones (frontalin and alpha pinene) suppressed attacks by spruce beetles in Lutz spruce on the Kenai National Wildlife Refuge by 87 and 99% respectively (Furniss et al. 1976,1979).

Field studies on the efficacy of slow-release formulations of liquid and granular MCH were undertaken in stands of Lutz spruce in south-central Alaska in 1983. Liquid and granular formulations (98% inert, 2% MCH) were applied by hand around felled uninfested spruce at three dosages: 4.6, 9.2, and 13.8 kg/ha. The 9.2 kg/ha dosage reduced beetle attacks and beetle brood by 70 and 61% respectively when compared to the untreated controls (Holsten and Werner 1984). Further studies indicated the cool micro-environment of the forest floor and the underside of felled trees was a major factor in preventing adequate elution of the MCH from granules formulated to elute at 20 C. In 1984, further field studies were conducted to bracket the dosage rates tested in 1983 (Holsten and Werner 1985). A slow release granular formulation (98% inert, 2% MCH) was applied at 6.9, 9.2, and 11.5 kg/ha along the top sides of felled Lutz spruce using a hand-held fertilizer spreader. The elution rates were 0.38, 0.50, and 0.63 g of MCH/ha/day; effective for a 30-60 day period. The elution rates were determined in the laboratory at 21 C at 50% relative humidity for 32 days as well as in the field. The results showed no significant differences ($P < 0.05$) between treated and untreated controls. This lack of efficacy was attributed to the lower than expected release rates of the MCH formulation. The laboratory tests showed an average loss of 3.7 g MCH/ha/day which falls within the optimal release rate (0.5-5.0

g/ha/day) determined in the 1983 study (Holsten and Werner 1984). The variation, however, around this mean was + 5.3 g/ha/day, which demonstrated that the elution rate was not constant. The field elution rate was only 1.81 g/ha/day for 32 days; 51% less than the laboratory elution rate. It appeared that the cold micro-environment of the forest floor retarded elution of MCH (Holsten and Werner 1986). Field tests for protecting individual trees using MCH-impregnated bubble caps were also undertaken in south-central Alaska with mixed results (Holsten and Werner 1987).

OBJECTIVE

In the fall of 1990, a 25.7 km natural gas line right-of-way (ROW) was constructed. The ROW debris consisted mostly of Lutz spruce and paper birch. The felled and cleared trees were decked along both sides of the ROW. Various land management agencies expressed concern over the possibility of spruce beetle build-up in the downed, decked material. The main concern was that large spruce beetle populations would emerge from the susceptible down host material and attack live standing trees bordering the right-of-way. Alaska Forest Service pest management specialists suggested a field experiment to test the efficacy of aerial and ground applied MCH to prevent or minimize spruce beetle buildup in the ROW debris. The following report summarizes the results of this field test.

MATERIALS & METHODS

Characteristics of MCH

MCH was formulated by Phero Tech Inc., Vancouver, B.C., Canada, into a controlled release bead consisting, by weight, of an inert polyethylene bead (98%) charged with 2% MCH. A similar controlled release formulation has significantly reduced Douglas-fir and spruce beetle attacks in Idaho when applied at a dosage rate of 4.6 kg/ha, eluting from 0.25 to 2.5 g MCH/ha/day for 60 days (Furniss et al. 1981). Previous studies in Alaska

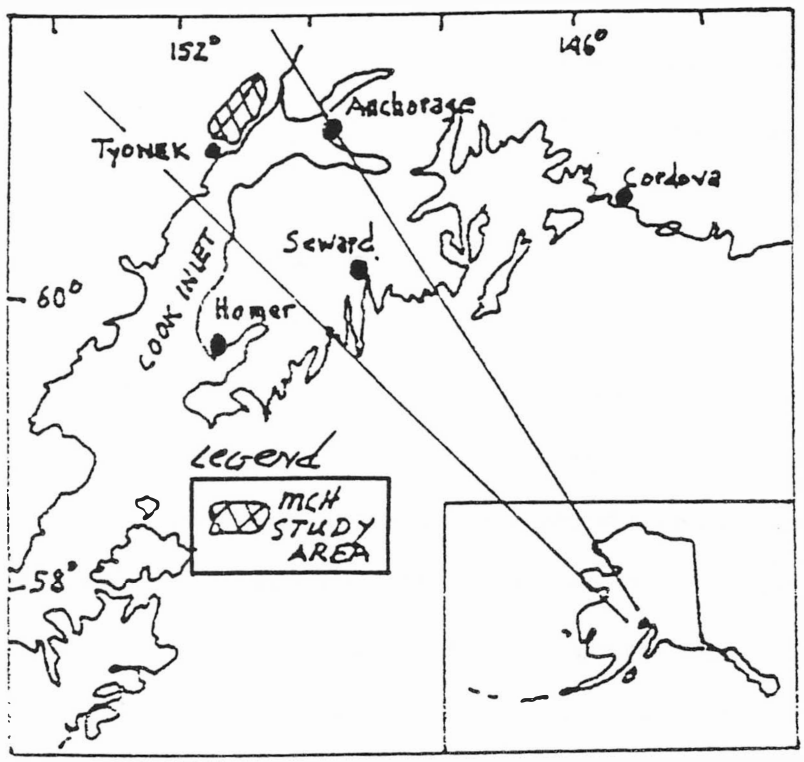

Fig. 1. *Location of the 1991 aerial and ground MCH application, Tyonek/Beluga, Alaska.*

(Holsten and Werner 1985) have shown that field elution rates of formulated plastic beads in a cool environment are 50% of the rates reported elsewhere. In the present study, two dosage rates 1X and 2X (4.6 & 9.2 kg/ha, respectively) were evaluated in the aerial study; 2X and 3X dosage rates (9.2 & 13.8 kg/ha, respectively) were evaluated in the ground test.

Study Areas

In the summer and fall of 1990 the Enstar Gas Company constructed a 25.7 km-long by 24 m-wide gasline ROW between Tyonek and Beluga on the west side of Cook Inlet southwest of Anchorage (Fig. 1). Trees were felled and decked along both sides of the ROW. The areas adjacent to the ROW were composed of Lutz spruce (60%) and paper birch (40%). These stands were interspersed with bog areas of black spruce (*P. mariana*) and blue-joint grass (*Calamgrostis* sp.). Populations of spruce beetles in this area were endemic. Previous FPM aerial surveys had recorded little spruce beetle activity in the area for the past five years.

Experimental Design

Aerial Application: The experiment consisted of three treatments replicated 7 times for a total of 21 plots. Treatments consisted of:

(1) MCH at 4.6 kg/ha

(2) MCH at 9.2 kg/ha

(3) Untreated control

Plot size was 0.51 ha (34 x 152 m) with a minimum distance of 152 m between plots. Treatments were randomly assigned to each plot. Plots were selected so that Lutz spruce comprised at least 50% of the log decks.

Ground Application: Consisted of three treatments replicated three times each for a total of 9 plots and included:

(1) MCH at 9.2 kg/ha

(2) MCH at 13.8 kg/ha

(3) Untreated control

Treatments were randomly assigned to each 0.02 ha plot.

Application Technology

Both the aerial and ground applications were carried out the week of May 13, 1991. Spruce beetle flight had not occurred at the time of applicaiton as determined by a random check of 100 uninfested logs.

Aerial: A modified Simplex 6400 fertilizer applicator was used for the aerial dispersion of the formulated MCH beads. This bucket applicator had been successfully used in prior MCH studies with Douglas-fir beetle (Furniss et al. 1982, 1982). The bucket was suspended approximately 15m above the forest canopy from a Bell Jet 206 helicopter flying about 72 km/hr. Swath width and application rates had been previously calibrated and standardized by prior testing carried out at the Anchorage Airport.

Ground: A modified Maruyama granule spreader was used for the ground application of MCH beads. Application rates and swath width were previously determined using a stop watch, weighted dosages of uncharged pellets, and a visual check of pellet dispersal.

Evaluation

A multi-stage sub-sampling scheme for estimating the total number of attacks and subsequent brood density was used during the week of August 19, 1991. Each aerial application plot was evaluated at each of five equally spaced locations. A coin toss at each of the five locations determined whether sampling occurred on the left or right side of the right-of-way. At each of the five sample locations, three spruce logs were selected; one from the top, one from the middle, and one from the bottom of the deck. Two 8.89 cm diameter circular samples were taken from each log; one from each side along mid-line of the log. The bark samples and all accompanying brood were placed in labeled zip-lock bags and returned to the laboratory for evaluation. Thirty samples were taken from each aerial application plot for a total of 210 samples per treatment. Sampling was carried out at only two locations per ground plot versus five locations in the aerial application plots as the ground plot size was significantly smaller than the aerial application plots. Twelve samples were taken from each ground application plot for a total of 36 samples per treatment. The number of spruce beetle attacks, number of galleries, gallery length in cm, number of spruce beetle adults, larvae, pupae, and callow adults were recorded from each bark sample. The number of *Ips* adults was also recorded from each sample.

Statistical Analysis

Data were tested for homogeneity, and if non-homogenous, arc sine transformations were undertaken. A one-way analysis of variance was first performed to determine if differences occurred between treatments; a two-way analysis of variance was then used to differentiate between effects of treatment on different positions of the log deck. That is, what effect did location of the sample log (top, middle, or bottom) have, if any, on treatment effects. Tukey's Studentized Range (HSD) test was used to identify subgroups that were significantly different at the 0.05% probability level.

RESULTS & DISCUSSION

Aerial Application

The aerial application of MCH formulated beads was undertaken and completed on the morning of May 15. Sunny, calm conditions prevailed permitting a smooth application. Spruce beetles had not flown prior to the aerial treatment. Statistical analyses of the data showed no significant differences between the two treatments and the untreated check plots. MCH did not significantly reduce the number of spruce beetle attacks and progeny as orginally anticipated. Table 1 presents the means (+ sem) for the more important variables analyzed such as number of attacks and number of spruce beetle brood. In fact, the check plots had a lower mean number (although not significant) of attacks and progeny than either of the treatments. This lack of significance is, in part, because of the low endemic spruce beetle population along the right-of-way resulting in low attack levels on the untreated check material. There was not sufficient beetle pressure to test the effectiveness of MCH treatments. For example, only 25 of the 210 check samples (12%) had entrance holes (attacks) and only 39% of the samples contained brood; the rest had zero counts.

However, with respect to the position of the sample log (top, middle, bottom), significantly fewer brood were found in the top logs than in either the middle or bottom logs. Previous studies have shown that spruce beetles prefer to attack and breed in shaded host material and resultant brood numbers are significantly reduced in these warmer, sunnier locations (Holsten et al. 1991, Hard and Holsten 1991, Hard 1992).

Ground Application

At first glance (Table 2) the ground applications appeared to be effective. Mean numbers of spruce beetle attacks and progeny appear to be reduced over that of the untreated control. Statistical analyses, however, again demonstrated that there were no significant differences between treatments and untreated controls

Table 1. MCH aerial application--mean* number of spruce beetle attacks, number of galleries, number of brood, and number of *Ips* adults by treatment replication.

TREATMENT	REP #	AV. # ATTACKS	AV. # GALLERIES	AV. # S.B. BROOD	AV. # IPS ADULTS
CONTROL	1	0.13 ± 0.02	0.43 ± 0.04	0.63 ± 0.09	1.20 ± 0.19
	2	0.23 ± 0.02	0.70 ± 0.04	2.87 ± 0.20	0.67 ± 0.02
	3	0.07 ± 0.01	0.40 ± 0.03	4.93 ± 0.66	1.57 ± 0.20
	4	0.03 ± 0.01	0.23 ± 0.02	1.73 ± 0.21	0.27 ± 0.02
	5	0.03 ± 0.01	0.47 ± 0.04	1.66 ± 0.17	0.03 ± 0.01
	6	0.00 ± 0.00	0.27 ± 0.02	4.10 ± 0.31	0.40 ± 0.03
	7	0.07 ± 0.01	0.27 ± 0.02	3.63 ± 0.38	0.30 ± 0.02
MEAN		**0.08 ± 0.00**	**0.39 ± 0.00**	**2.79 ± 0.05**	**0.63 ± 0.02**
T-1 (4.6 kg/ha)	1	0.07 ± 0.01	0.31 ± 0.02	1.97 ± 0.18	1.28 ± 0.15
	2	0.07 ± 0.01	0.50 ± 0.04	2.07 ± 0.23	0.20 ± 0.02
	3	0.20 ± 0.02	0.87 ± 0.06	4.13 ± 0.24	1.03 ± 0.26
	4	0.27 ± 0.02	0.63 ± 0.04	3.50 ± 0.40	0.13 ± 0.01
	5	0.10 ± 0.01	0.43 ± 0.03	5.00 ± 0.35	1.60 ± 0.28
	6	0.10 ± 0.01	1.14 ± 0.06	7.67 ± 0.37	0.10 ± 0.02
	7	0.07 ± 0.01	0.13 ± 0.03	3.73 ± 0.37	0.17 ± 0.04
MEAN		**0.13 ± 0.00**	**0.57 ± 0.01**	**3.98 ± 0.05**	**0.64 ± 0.02**
T-2 (9.2 kg/ha)	1	0.07 ± 0.01	0.63 ± 0.03	5.37 ± 0.56	0.87 ± 0.09
	2	0.20 ± 0.02	0.67 ± 0.04	0.97 ± 0.13	0.97 ± 0.13
	3	0.07 ± 0.01	0.33 ± 0.04	2.03 ± 0.17	0.37 ± 0.08
	4	0.10 ± 0.01	0.66 ± 0.04	3.59 ± 0.22	0.07 ± 0.02
	5	0.10 ± 0.01	0.87 ± 0.07	4.40 ± 0.34	0.57 ± 0.10
	6	0.07 ± 0.01	1.07 ± 0.06	5.37 ± 0.26	0.07 ± 0.01
	7	0.03 ± 0.01	0.37 ± 0.04	1.10 ± 0.31	0.23 ± 0.04
MEAN		**0.09 ± 0.00**	**0.66 ± 0.01**	**3.26 ± 0.04**	**0.45 ± 0.01**

*Means ± SD is based on 30 samples per replication.

Table 2. MCH ground application--mean* number of spruce beetle attacks, number of galleries, number of brood, and number of *Ips* adults by treatment replication.

TREATMENT	REP #	AV. # ATTACKS	AV. # GALLERIES	AV. # S.B. BROOD	AV. # IPS ADULTS
CONTROL	1	0.08 ± 0.03	0.25 ± 0.07	0.00 ± 0.00	0.17 ± 0.07
	2	0.08 ± 0.03	0.75 ± 0.16	3.25 ± 0.69	1.00 ± 0.41
	3	0.08 ± 0.03	0.42 ± 0.08	4.0 ± 0.51	0.00 ± 0.00
MEAN		**0.08 ± 0.01**	**0.47 ± 0.04**	**2.42 ± 0.18**	**0.39 ± 0.08**
T-1 **9.2 kg/ha**	1	0.00 ± 0.00	0.42 ± 0.06	0.17 ± 0.07	0.00 ± 0.00
	2	0.17 ± 0.04	0.42 ± 0.13	2.92 ± 0.79	0.00 ± 0.00
	3	0.00 ± 0.00	0.25 ± 0.07	1.08 ± 0.37	0.00 ± 0.00
MEAN		**0.01 ± 0.00**	**0.36 ± 0.03**	**1.39 ± 0.17**	**0.00 ± 0.00**
T-2 13.8 kg/ha	1	0.00 ± 0.00	0.25 ± 0.04	0.42 ± 0.17	0.17 ± 0.07
	2	0.00 ± 0.00	0.25 ± 0.04	0.58 ± 0.12	0.00 ± 0.00
	3	0.00 ± 0.00	0.17 ± 0.07	0.67 ± 0.07	0.50 ± 0.14
MEAN		**0.00 ± 0.00**	**0.22 ± 0.02**	**0.56 ± 0.04**	**0.22 ± 0.03**

*Means ± SD is based on 12 samples per replication.

with respect to the variables analyzed. However, there were significant differences with respect to number of attacks and the position of the sample log. There were more attacks on the top sample log of the control treatment than any of the other treatments. However, the total number of attacks was extremely low overall (5 attacked samples out of 108) making this difference biologically insignificant. Similar to the aerially treated plots only 12% of the ground check samples contained entrance holes; 39 percent of the control samples contained spruce beetle brood. These numbers are indicative of the low endemic spruce beetle populations in the ground treatment area.

We orginally considered placing spruce beetle pheromone baits on all log decks within the study area regardless of treatment in order to "force" dispersing beetles into the study area. This would reduce the number of zero counts on the control plots and provide for sufficient beetle pressure to adequately test the effectiveness of the MCH treatments. This is a common practice in semiochemical research studies and provides for a conservative test. However, there was considerable concern by various State agencies and local civic groups residing in the area over the possiblity of a spruce beetle outbreak developing along the right-of-way as a result of beetles breeding in the downed ROW logs. Consequently, it would not have been prudent to artificially increase spruce beetle populations in the untreated control logs.

On a positive note, the overall risk of spruce beetle population buildup in the downed right-of-way material appears to be low. Approximately 61% of the MCH treatment and control samples along the entire ROW were unattacked with no brood present indicating a low endemic population in the area.

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APPENDIX A

SPRUCE BEETLE

Dendroctonus rufipennis (Kirby)
(Coleoptera:Scolytidae)

HOSTS:	White, Sitka, Lutz, and rarely black spruce.
DISTRIBUTION:	Wherever spruce is found; a serious forest pest in southcentral Alaska throughout Cook Inlet and Kenai Peninsula.
DAMAGE:	Larvae feed beneath bark, usually killing affected trees.
DESCRIPTION:	Adult spruce beetles are maroon to black, cylindrical in shape, approximately 5 mm long and 3 mm wide. Larvae are stout, white, legless grubs, 6 mm long when full-grown. The pupae are soft-bodied, white, and have some adult features.
BIOL-OGY:	The life cycle of the spruce beetle may vary from one to three years, with a two-year cycle being the most common. Temperature plays an important part in determining the length of time required for beetle development.

Adult beetles become active in the spring (late May -- early June) when air temperatures reach a threshold of 16o C (61o F). At this time, beetles emerge from trees in which they overwintered and fly in search of new host material. These dispersal flights may be short-range even though beetles are capable of flying for several miles without stopping.

Spruce beetles prefer to attack the sides and bottom surfaces of windthrown or other down materials which have been on the ground less than one year. In the absence of such host material, large-diameter live trees may be attacked instead, and if beetle populations are high, these trees may be killed.

Beetle attacks, whether on windthrown or on standing timber, are mediated by pheromones which insure that individual trees will be attacked "en masse", and fully colonized by subsequent broods. Trees that are mass-attacked form attractive centers centers which result in groups of trees being killed by spillover attacks.

Female beetles initiate attacks and begin constructing an egg gallery in the cambium parallel to the grain of the tree. They are joined by males and after mating, lay eggs in small niches along the sides of the egg gallery. Most eggs will hatch by August. As they feed in the cambium, larvae construct their own galleries perpendicular to the egg gallery. Normally, spruce beetles pass the first winter in the larval stage, resume feeding in the next spring, and pupate by summer. About two weeks later, pupae transform into adults which pass the second winter, either in the old pupation site, or more commonly, in the bases of infested trees. The following spring, two years after initial attack, the new adults emerge and attack new host material. In some years when temperatures are abnormally high, or on certain warmer microsites, spruce beetles may complete their development within one season and new adults will emerge one year after attack.

Most major outbreaks of spruce beetle have originated from stand disturbances-- blowdown, logging, or right-of-way clearance. Stand susceptibility to beetle attack is influenced by stocking, with slow growth and moisture stress playing an important part in predisposing trees to attack.